Sea level and ocean/land/ice observations and models

Science discussions with Mike Freilich
Jet Propulsion Laboratory
December 10, 2010

- Sea level and altimetry (Lee-Lueng Fu)

- Land/ice observations and models (Erik Ivins)

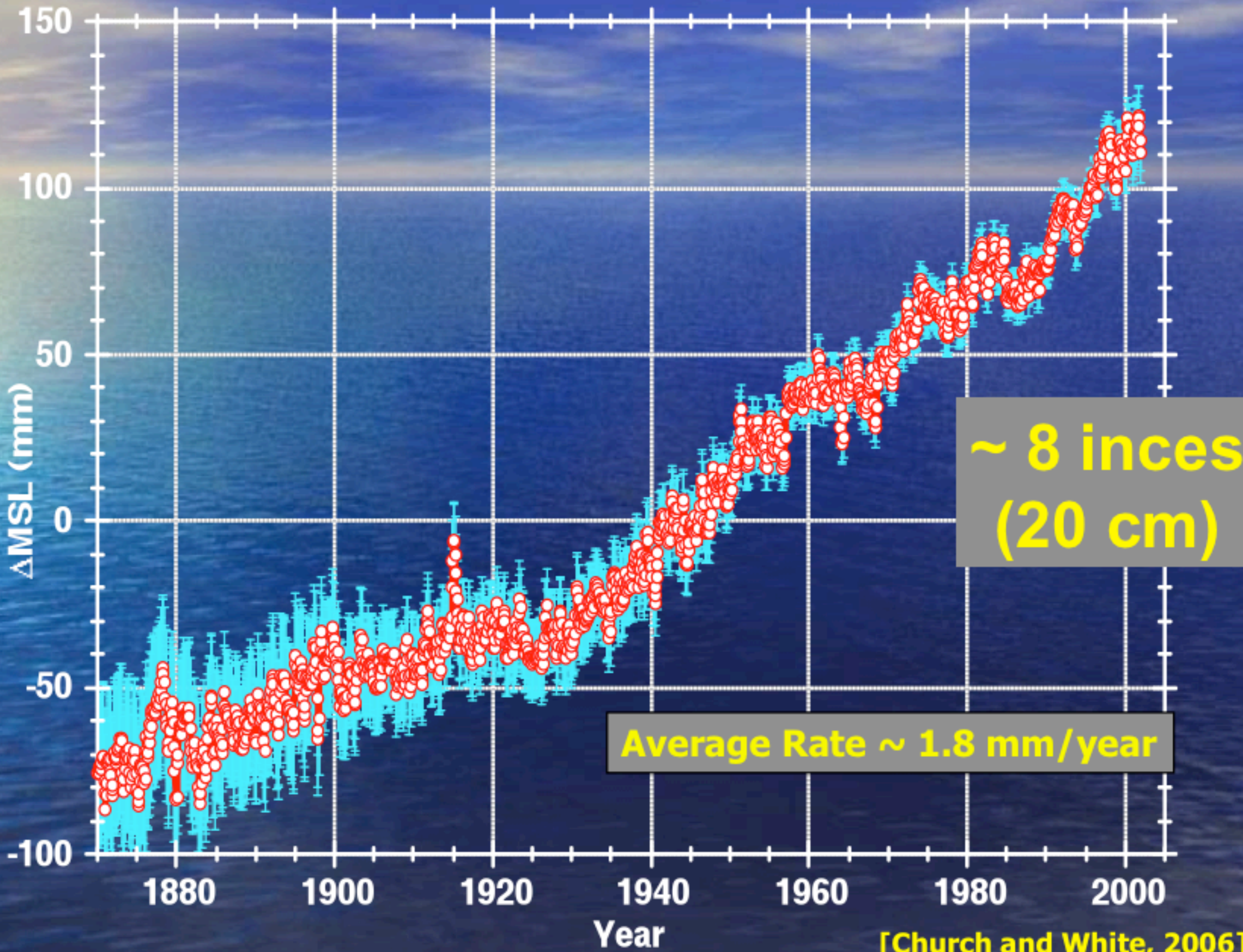
- ISSM: ice sheet data assimilation (Eric Larour)

- ECCO2: ocean and sea ice data assimilation (Dimitris Menemenlis)

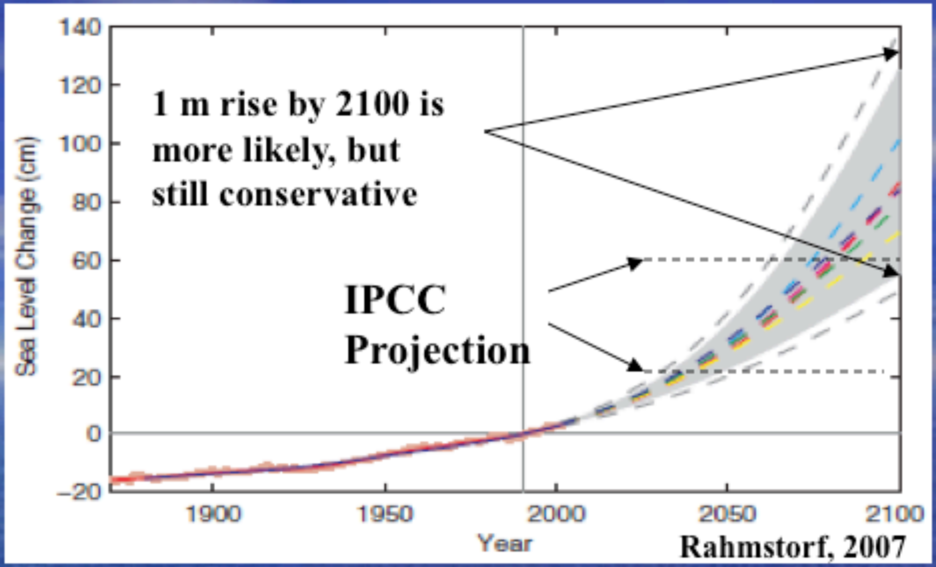
- Sea ice observations and models (Ron Kwok)

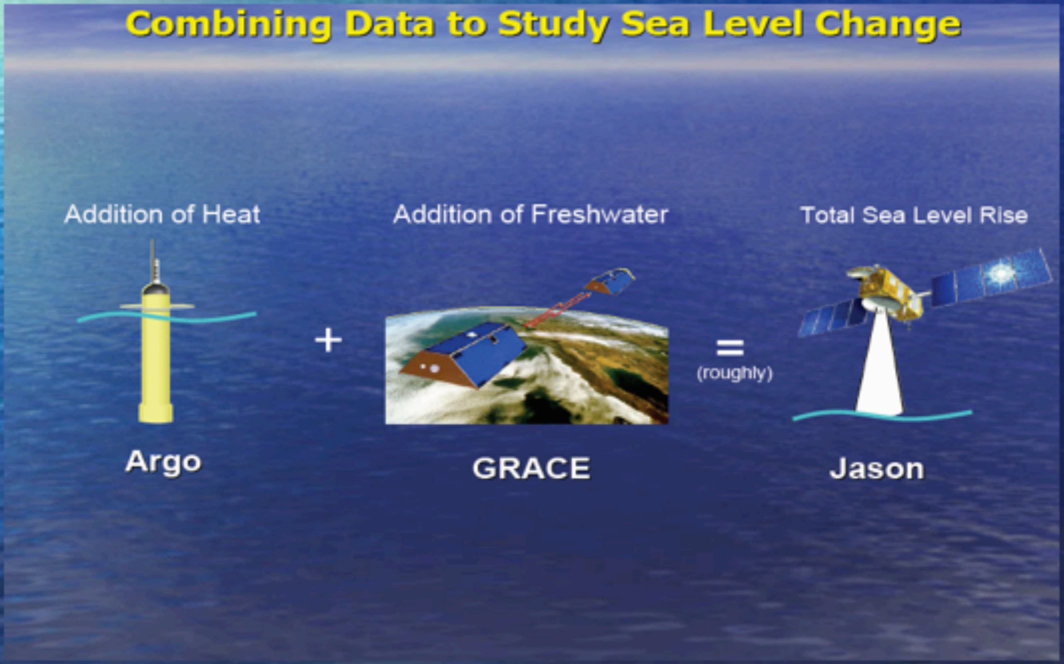
- Ice sheet/ocean interactions (Eric Rignot)

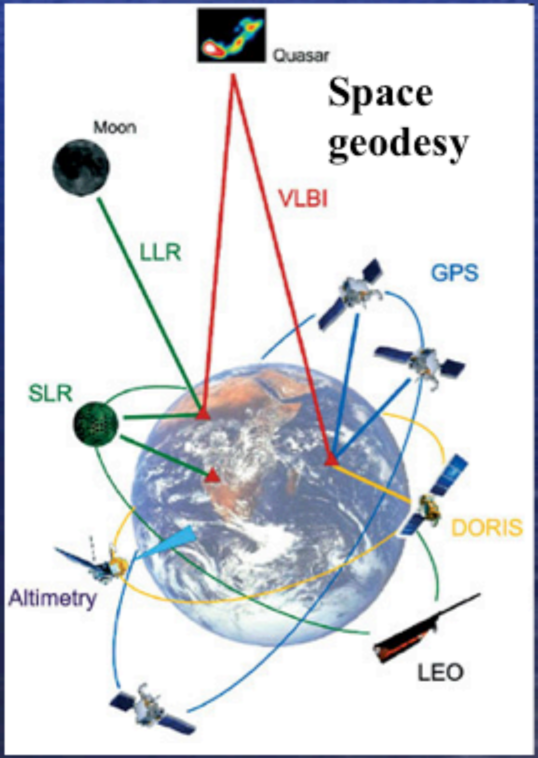
NASA Owns the Sea Level Problem



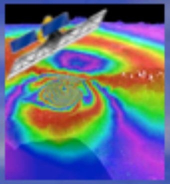
Prediction of sea level and its geographic patterns is a grand challenge for the coming decades





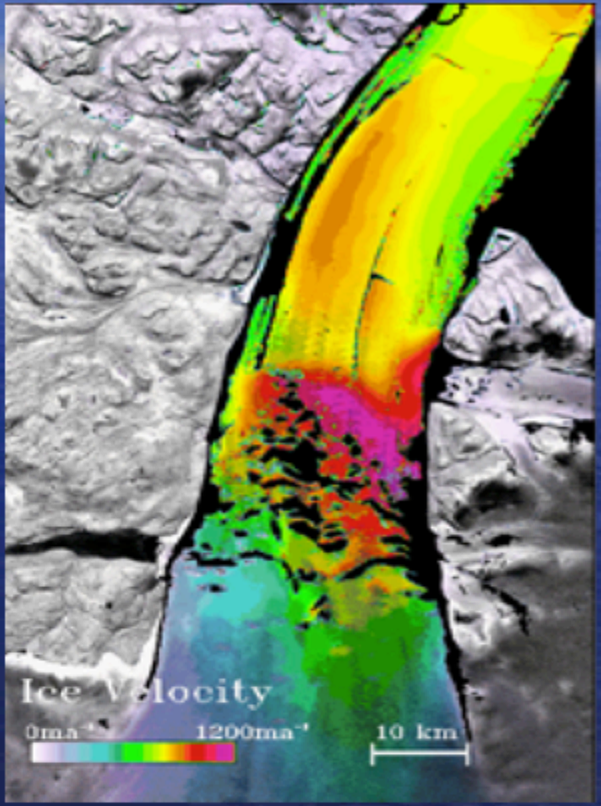


Melting Ice Sheet is the Wild Card…



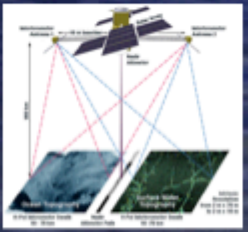
DESDynI

- Repeat-pass radar interferometry allows us to measure how quickly ice sheets are moving from space



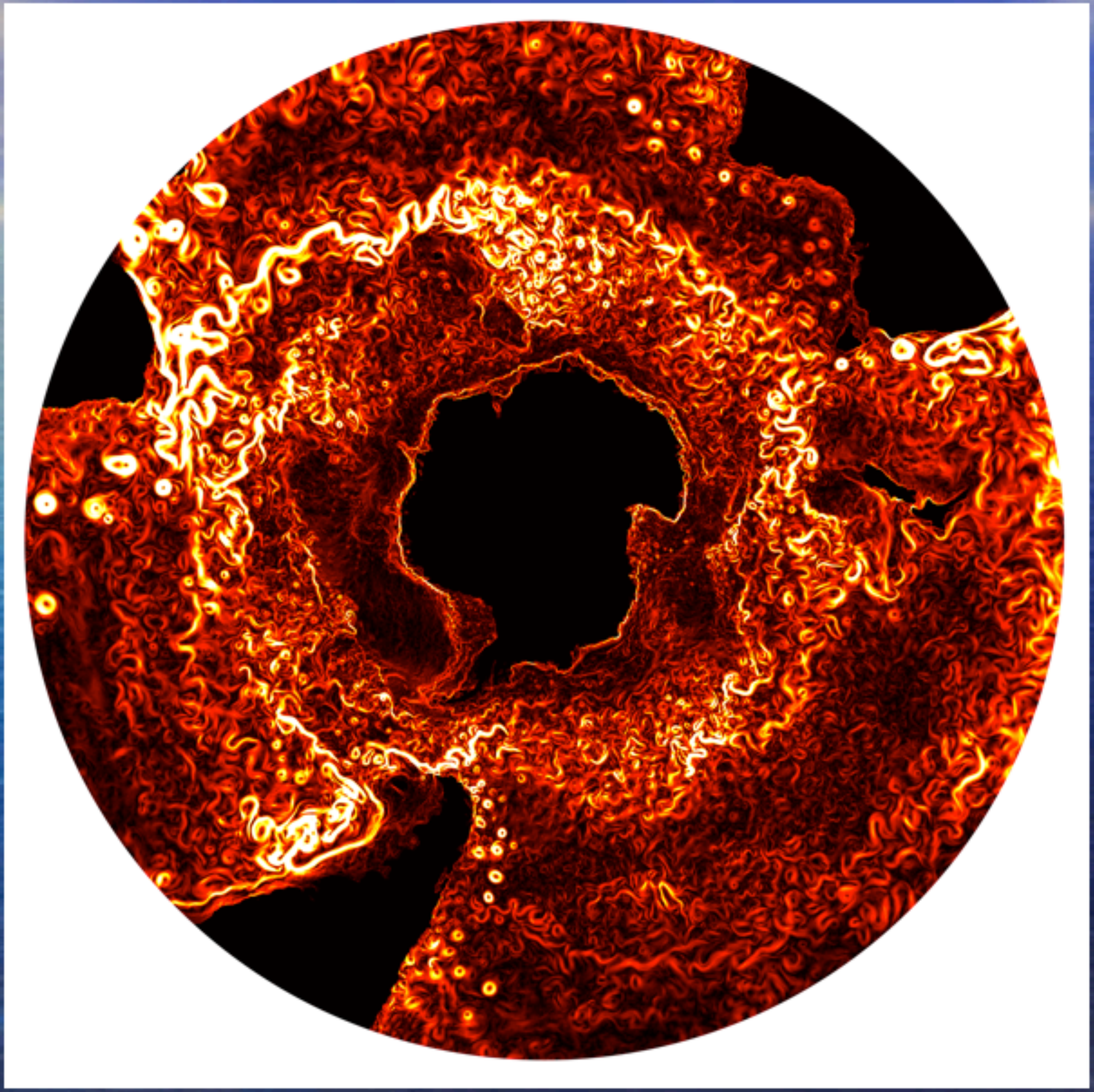
Ice shelves holding up the ice sheets

- Wide-swath altimetry allows us to measure the ocean currents transporting heat to melt the ice shelves

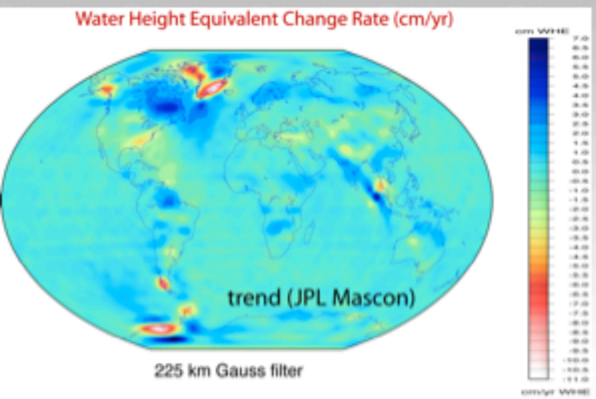


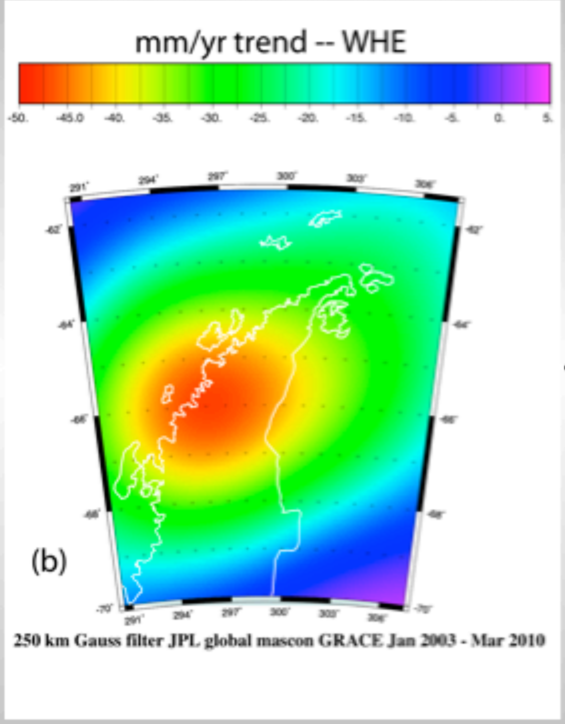
SWOT

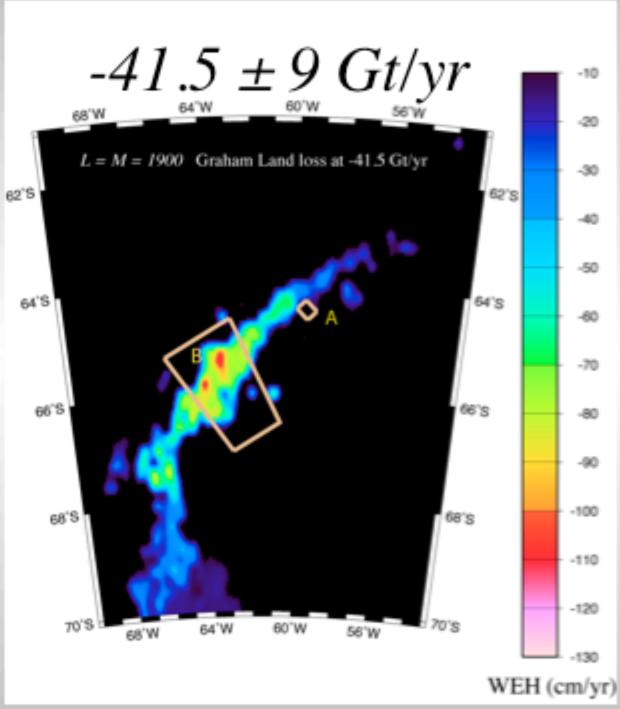
JPL Ocean-Ice Modeling Effort



8-yr GRACE ice loss record







GRACE trends over 8 Years: Deduction of Cryospheric to Ocean Mass Transport: Roughly large enough to explain ongoing sea level rise

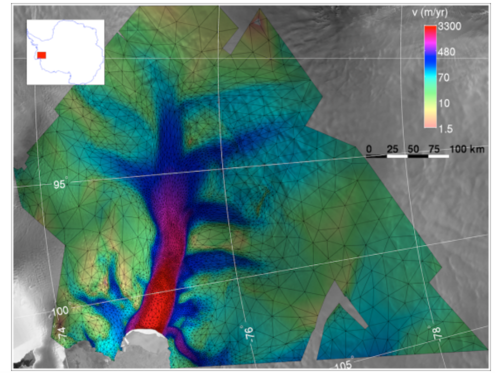
JPL Global Mascon solution At the Antarctic Peninsula

Model ice and solid Earth Isostatic response (GPS data) & apply smoothing - compare to altimetry

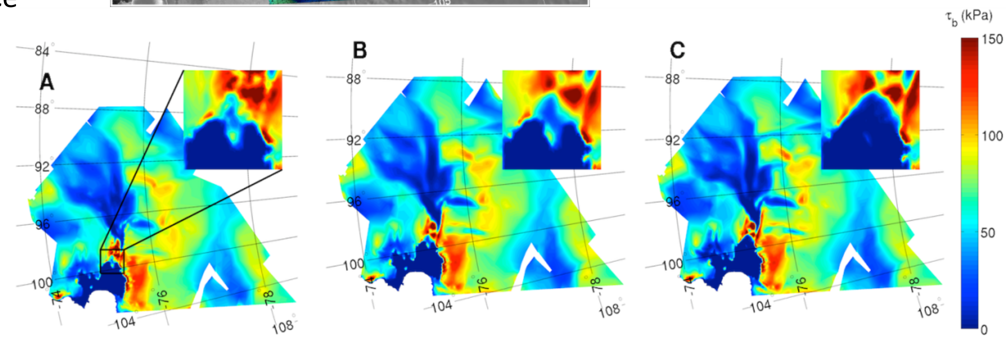
Antarctica -> 220-246 Gt/yr (Chen et al. 2009)
Antarctica -> 100 ± 67 Gt/yr (GIA corrected: Riva et al., 2009)
Greenland -> 137-159 accelerated to 267-28 Gt/yr (Velicogna, 2009)

ISSM: Ice Sheet System Model.

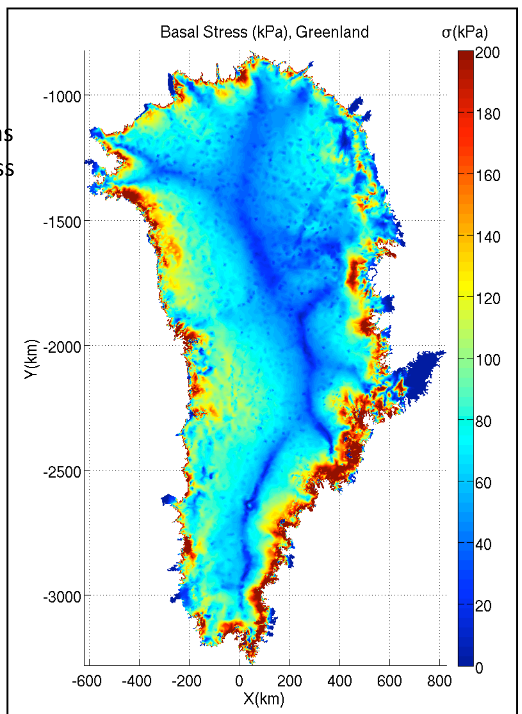
• finite element model, anisotropic meshing -> refine model where physics are warranted.
•large scale capabilities: high resolution (1km horizontal, 10 layers vertical).
• multi-model: 2D, 3D higher-order and 3D Full-Stokes
• data assimilation: optimize unknown parameters (basal stress and ice rigidity) using the adjoint model (inverse control method) and surface velocity data from InSAR.



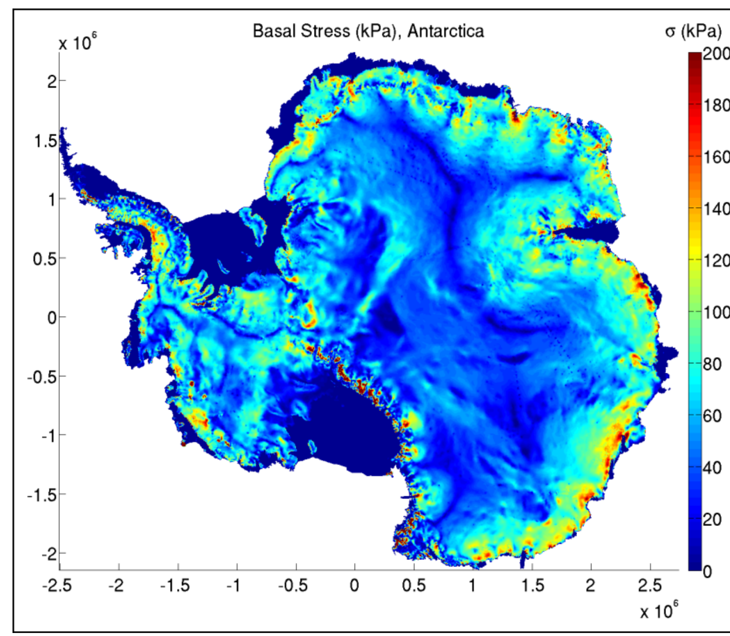
Pine Island Glacier: assimilation of basal stress using 2D (frame A), 3D Blatter/Pattyn (frame B) and 3D Full-Stokes (frame C) models. Basal stress near the grounding line is extremely model dependent -> need for Full-Stokes locally. Morlighem et al 2010.



Large scale inversion of basal stress over the Greenland Ice Sheet. A Full-Stokes model was used to inverse the basal stress using control methods and InSAR surface velocities from Joughin 2010.

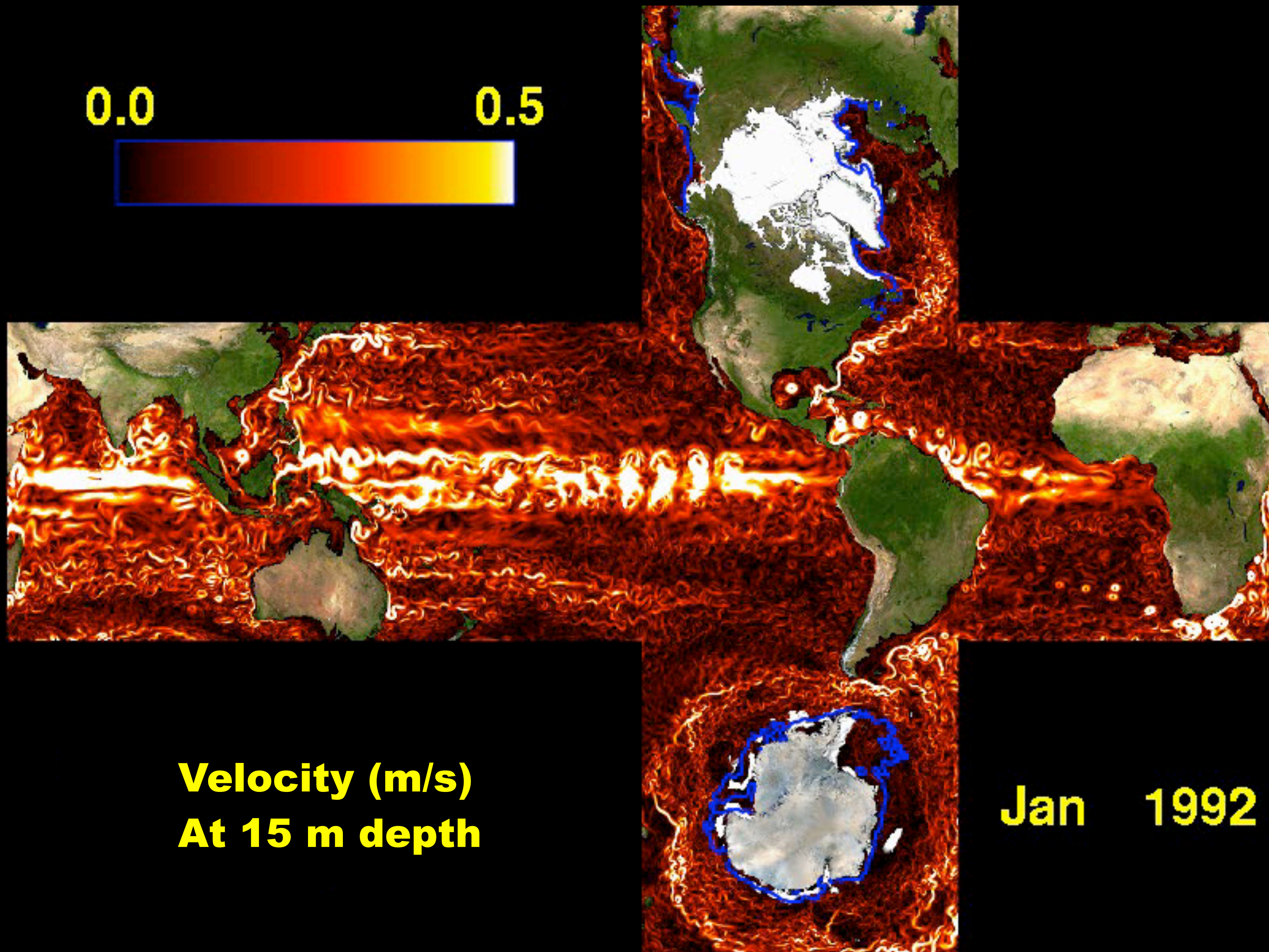


Large scale inversion of basal stress over the Antarctica Ice Sheet. A 3F Blatter/Pattyn model was used to invert the basal stress using control methods and InSAR surface velocities (Rignot, unpublished). Larour, GRL 2010 in revision.



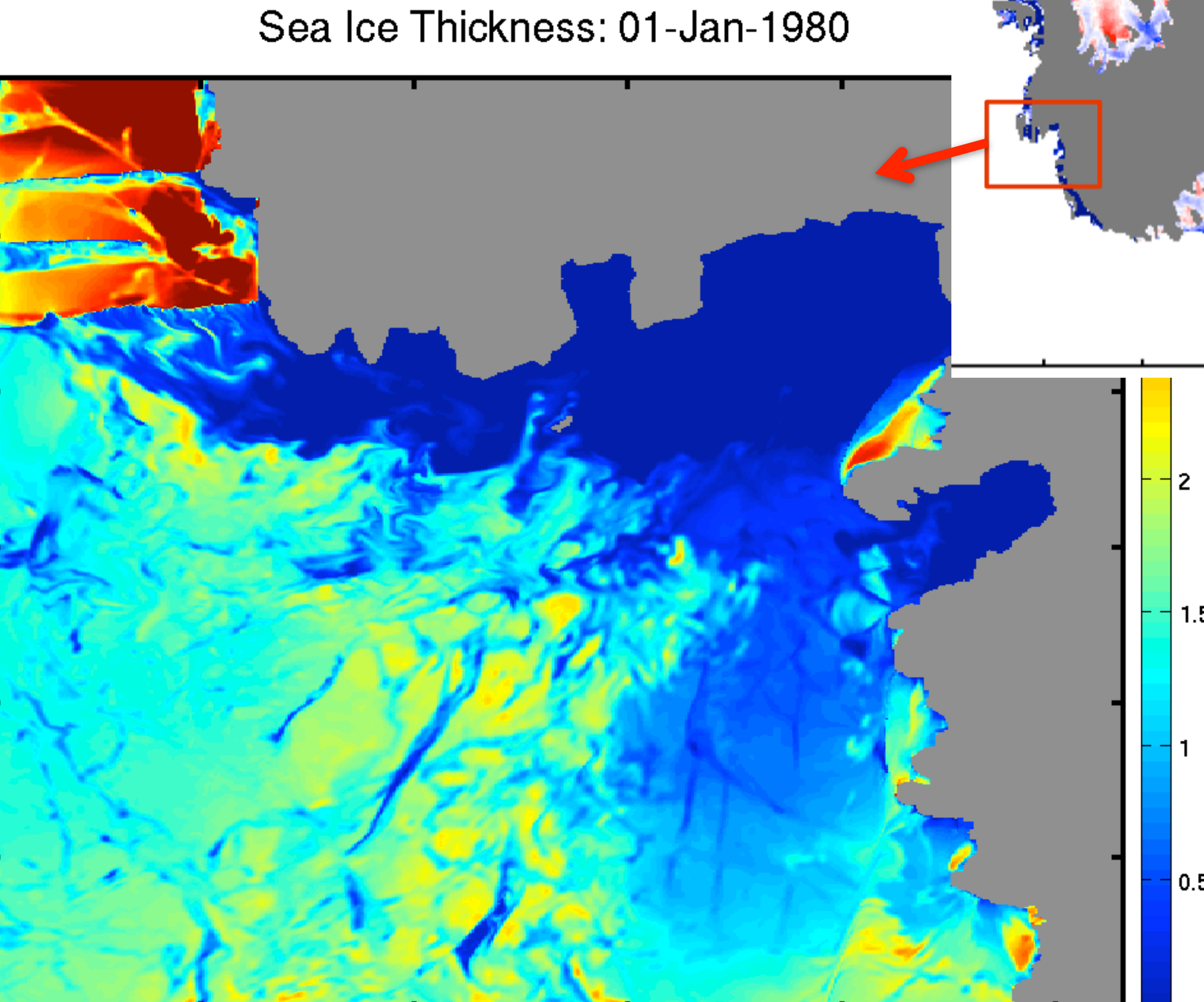
ECCO2

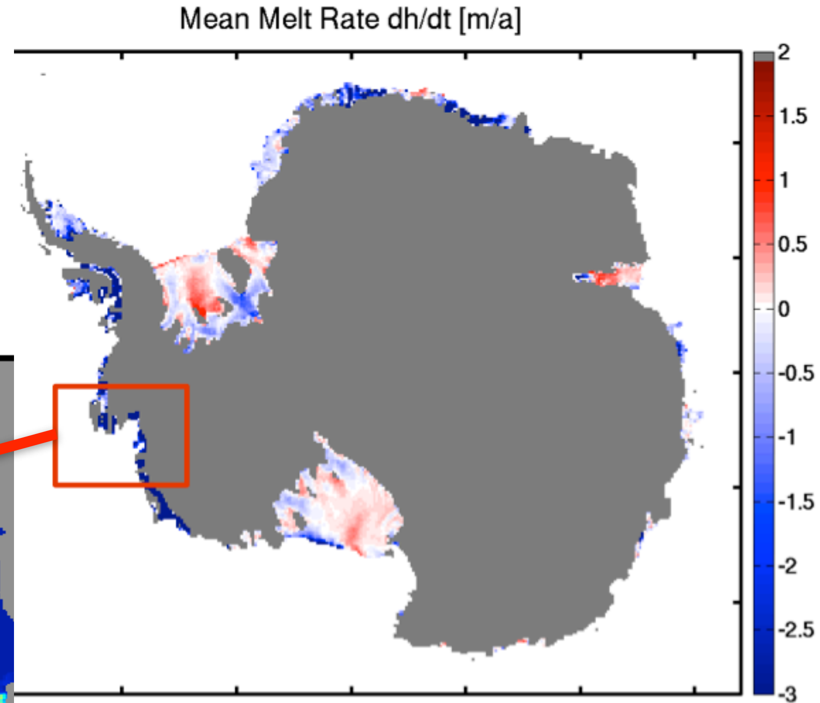
Eddying global-ocean and sea-ice data synthesis for improved estimates and models of ocean carbon cycle, understanding recent evolution of polar oceans, monitoring time-evolving term balances within and between different components of the Earth system, and many more science applications.



Ice shelf cavities in ECCO2

(Michael Schodlok, JPL/JIFRESSE)



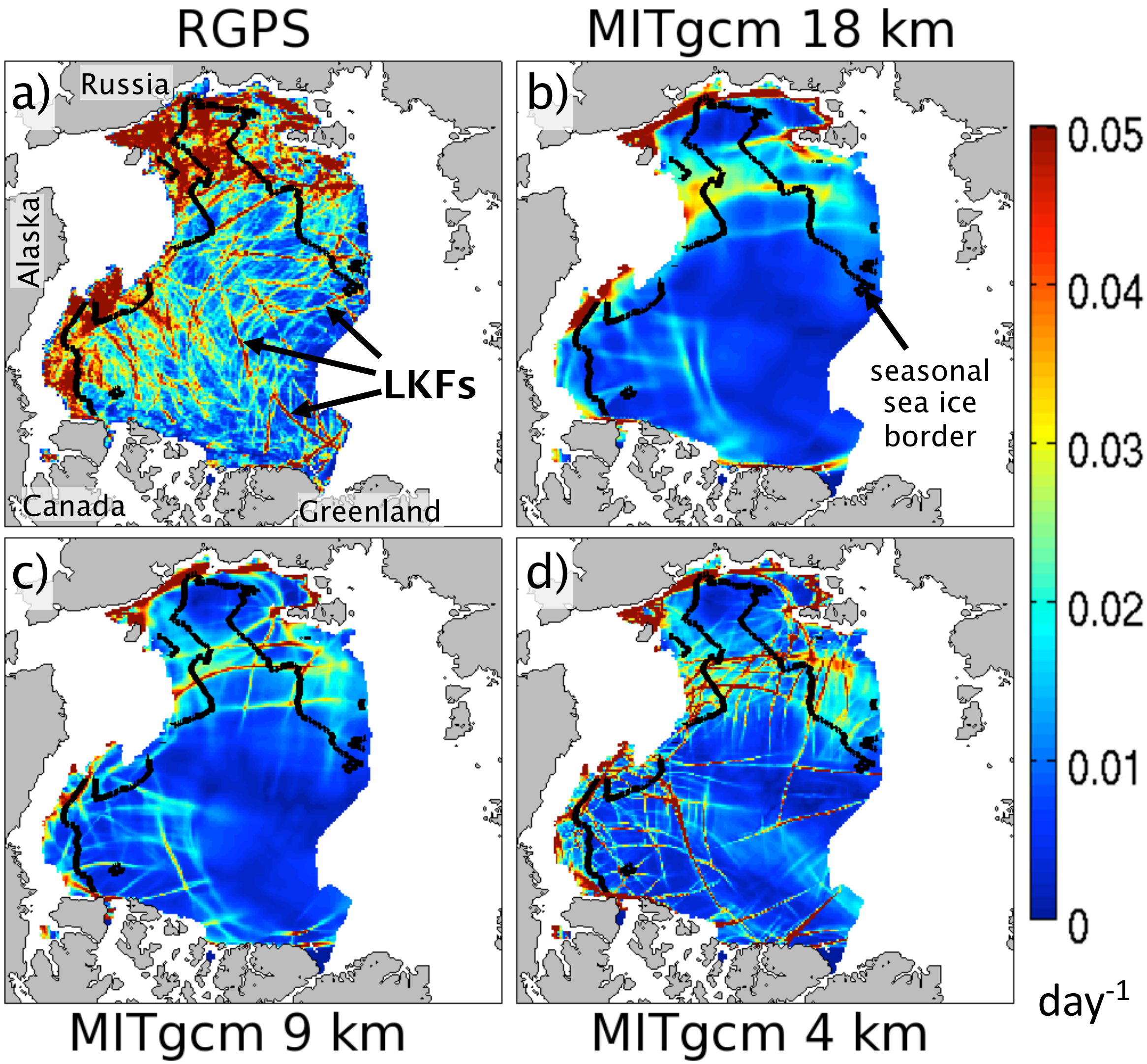


ECCO2 basal melt estimate (59 mSv) is double previous (BRIOS) estimate, more consistent with mass loss derived from ICESat/GLAS.

Sea ice in the coupled system is at the heart of the "ice pump" mechanism governing sub-ice shelf cavity circulation and an essential ingredient in the production of very dense High Salinity Shelf Water, which is the source of Antarctic Bottom Water.

Observations of sea ice kinematics

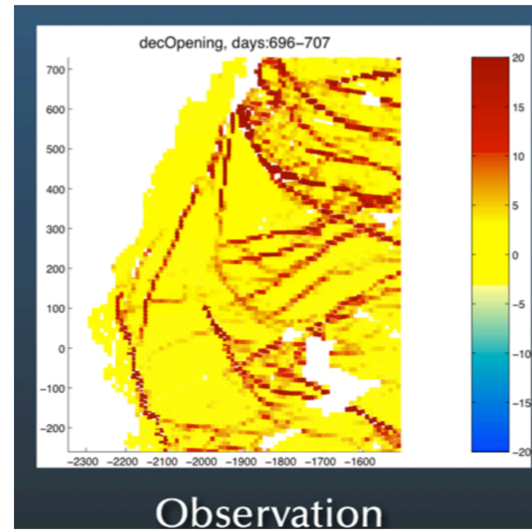
(Ron Kwok and Gunnar Spreen, JPL)

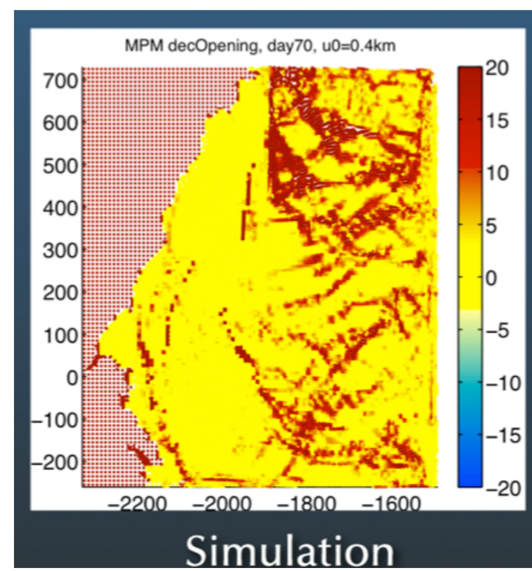


Nov. 1997 sea ice deformation: $D = \sqrt{\mathrm{div}^2 + \mathrm{shear}^2}$

New sea ice constitutive model

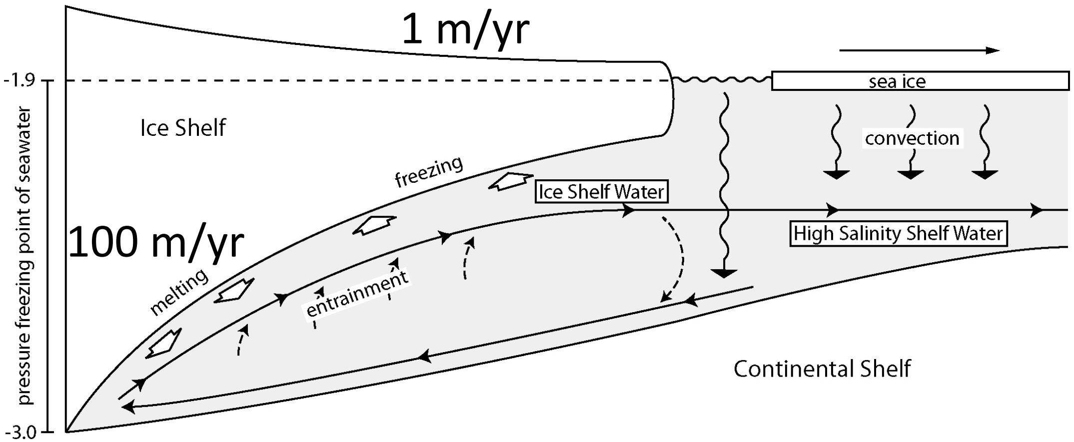
(Deborah Sulsky, UNM and Ron Kwok, JPL)

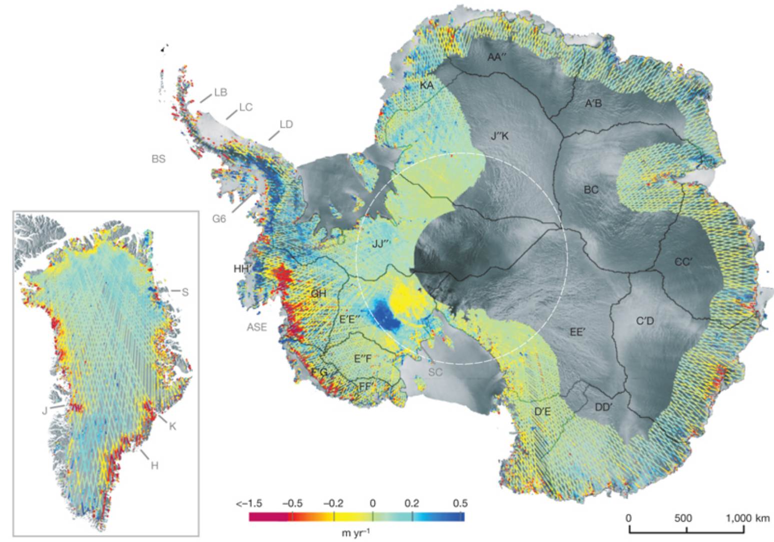




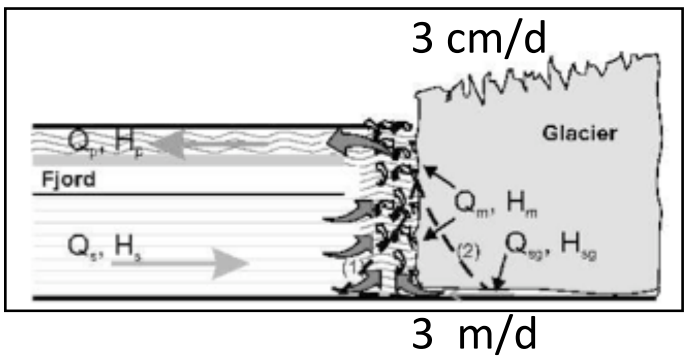
Ice-sheet/Ocean Interactions

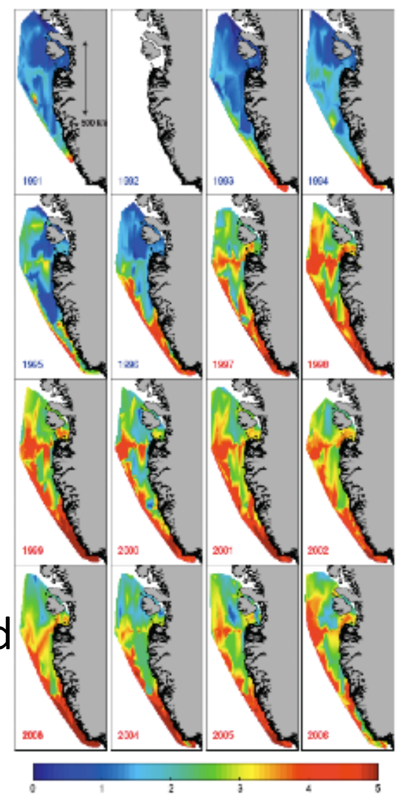
Rapid ice sheet changes at low elevation

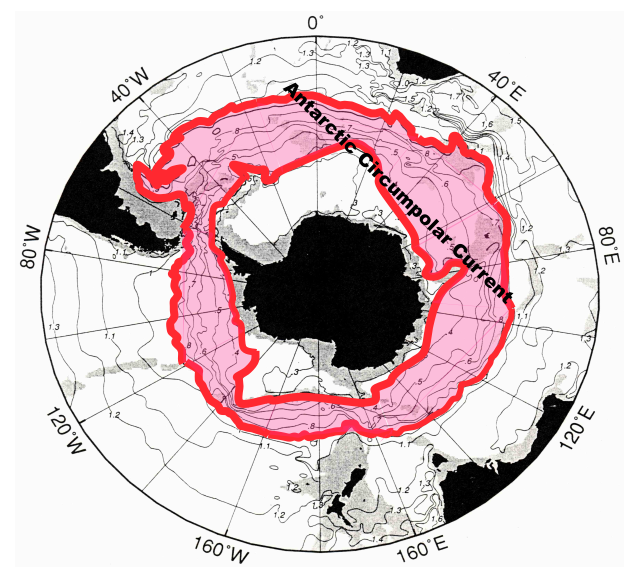




Sub-aqueous melt rates > 100 surface melt rates







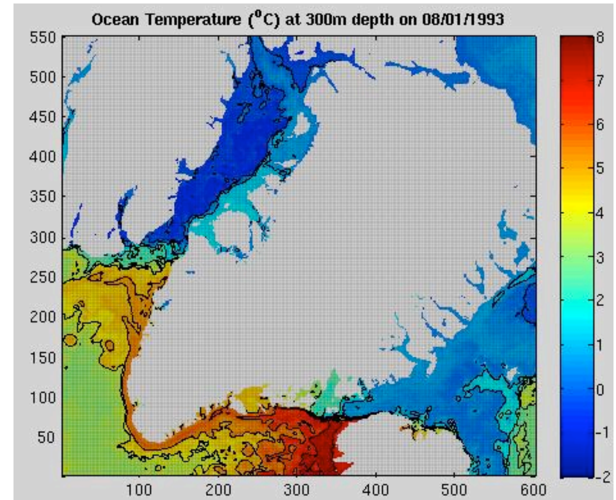
- Surface mass balance steady in Antarctica but declining 100% by decade in Greenland due to enhanced melt.
- Yet surface melt alone cannot explain rapid changes in glacier dynamics.
- Why? Ice sheets melt from the bottom

Significant oceanic changes but impact on land ice is poorly documented

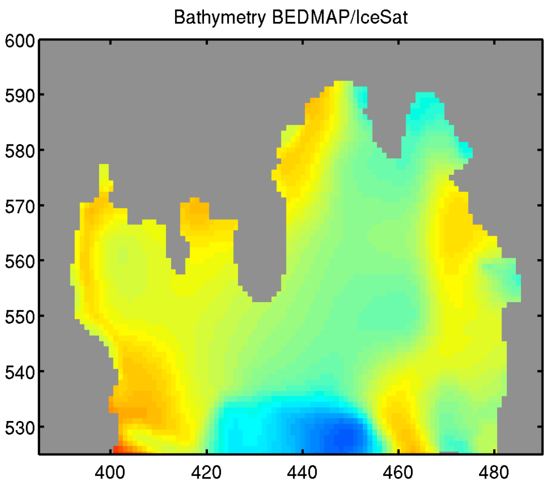
NASA plays a critical role:

- IceBridge: dhdt, H, bathymetry
- ECCO2 model/data assimilation
- ISSM model/data assimilation

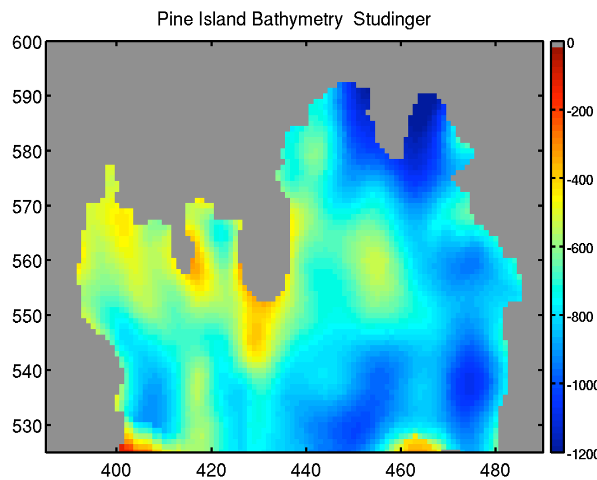
→ high-res, continental view.



Unrealistically low melt



Consistent with satellite estimates



Oceanic change migrates northwest